



BSI Standards Publication

# Safety of machinery — Electro-sensitive protective equipment

Part 4-3: Particular requirements for equipment using vision based protective devices (VBPD) — Additional requirements when using stereo vision techniques (VBPDST)

### **National foreword**

This Published Document is the UK implementation of IEC/TS 61496-4-3:2015.

The UK participation in its preparation was entrusted to Technical Committee MCE/3, Safeguarding of machinery.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2015.

Published by BSI Standards Limited 2015

ISBN 978 0 580 80409 0

ICS 13.110; 29.260.99

**Compliance with a British Standard cannot confer immunity from legal obligations.**

This Published Document was published under the authority of the Standards Policy and Strategy Committee on 31 May 2015.

### **Amendments/corrigenda issued since publication**

<b>Date</b>	<b>Text affected</b>
-------------	----------------------

---



# TECHNICAL SPECIFICATION



---

**Safety of machinery – Electro-sensitive protective equipment –  
Part 4-3: Particular requirements for equipment using vision based protective  
devices (VBPD) – Additional requirements when using stereo vision techniques  
(VBPDEST)**

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

---

ICS 13.110; 29.260.99

ISBN 978-2-8322-2611-7

**Warning! Make sure that you obtained this publication from an authorized distributor.**

## CONTENTS

FOREWORD.....	5
INTRODUCTION.....	7
1 Scope.....	8
2 Normative references .....	9
3 Terms and definitions .....	9
Abbreviated terms.....	12
4 Functional, design and environmental requirements .....	12
4.1 Functional requirements.....	12
4.1.2 Sensing function.....	12
4.1.3 Types of ESPE .....	15
4.1.6 Zone with limited detection capability.....	15
4.2 Design requirements.....	16
4.2.2 Fault detection requirements .....	16
4.2.12 Integrity of the VBPDST detection capability.....	17
4.2.13 Test pieces for type testing.....	19
4.2.14 Wavelength .....	21
4.2.15 Radiation intensity .....	21
4.2.16 Mechanical construction .....	21
4.3 Environmental requirements .....	21
4.3.1 Ambient air temperature range and humidity.....	21
4.3.5 Ambient light intensity.....	21
4.3.6 Light interference.....	21
4.3.7 Pollution interference.....	22
4.3.8 Manual interference.....	22
4.3.9 Optical occlusion (eclipsed by small object).....	23
4.3.10 Drift or ageing of components.....	23
5 Testing.....	23
5.1 General.....	23
5.1.2 Test conditions .....	23
5.1.4 Test conditions and test plan .....	24
5.2 Functional tests .....	24
5.2.1 Sensing function.....	24
5.2.9 Verification of optical performance.....	28
5.2.10 Wavelength .....	28
5.2.11 Radiation intensity .....	28
5.3 Performance testing under fault conditions .....	28
5.3.2 Type 1 ESPE .....	28
5.3.3 Type 2 ESPE .....	28
5.3.4 Type 3 ESPE .....	29
5.3.5 Type 4 ESPE.....	29
5.4 Environmental tests .....	29
5.4.2 Ambient temperature variation and humidity .....	29
5.4.4 Mechanical influences .....	29
5.4.6 Light interference.....	30
5.4.7 Pollution interference.....	36
5.4.8 Manual interference.....	37

5.4.9	Optical occlusion .....	37
6	Marking for identification and for safe use .....	38
6.1	General.....	38
7	Accompanying documents .....	38
Annex A (normative)	Optional functions of the ESPE .....	40
A.9	Setting the detection zone and/or other safety-related parameters .....	40
A.9.1	Functional requirements .....	40
A.9.2	Verification .....	40
A.10	Selection of multiple detection zones .....	41
A.10.1	Functional requirements .....	41
A.10.2	Verification .....	41
Annex B (normative)	Catalogue of single faults affecting the electrical equipment of the ESPE, to be applied as specified in 5.3 .....	42
B.7	Imaging sensor .....	42
Annex AA (informative)	The positioning of VBPDST employing a volume as a detection zone in respect of parts of the human body .....	43
AA.1	Calculation of distances for electro-sensitive protective equipment employing vision based protective devices (VBPDST).....	43
AA.1.1	General .....	43
AA.1.2	Calculation of the overall minimum distance $S_0$ .....	43
AA.1.3	Vision based protective devices with a detection capability > 40 mm and ≤ 55 mm .....	44
AA.1.4	Vision based protective devices with a detection capability > 55 mm and ≤ 200 mm .....	45
AA.1.5	Examples of detection zone and tolerance zone .....	45
AA.2	Application examples for body detection of a VBPDST employing a volume as a detection zone.....	49
Annex BB (informative)	Relationship between position accuracy and tolerance zones for VBPDST .....	51
BB.1	Probability of detection .....	51
BB.2	Tolerance zone related to probability .....	52
BB.3	Determination of tolerance zone for systems not providing object distance information.....	52
BB.4	Determination of tolerance zone for systems providing distance information .....	53
BB.5	Tolerance zone related to systematic interferences.....	54
BB.6	Adding the tolerance zone on the outer border of the detection zone .....	54
Annex CC (informative)	Basic principles of physics for contrast of convex homogeneous bodies .....	56
CC.1	Illumination on a surface element.....	56
CC.2	Brightness of a surface element.....	58
Bibliography.....		63
Figure 1 – Image planes in imaging device of a VBPDST .....		10
Figure 2 – 3D view of a vision based protective device using stereo vision techniques (VBPDST).....		13
Figure 3 – 2D view of a vision based protective device using stereo vision techniques (VBPDST).....		14
Figure 4 – Examples for periodic surface structures on the background .....		28
Figure 5 – Test setup for indirect light interference on the background.....		34

Figure 6 – Test setup for VBPDST of identical design with PAPT .....	35
Figure 7 – Test setup for direct light interference on the sensing device .....	36
Figure AA.1 – Minimum distance $S$ – Example 1 .....	45
Figure AA.2 – Overall minimum distance $S_0$ without tolerance zone – Example 1 .....	46
Figure AA.3 – Overall minimum distance $S_0$ including tolerance zone – Example 1 .....	46
Figure AA.4 – Minimum distance $S$ – Example 2 .....	47
Figure AA.5 – Overall minimum distance $S_0$ without tolerance zone – Example 2 .....	48
Figure AA.6 – Overall minimum distance $S_0$ including tolerance zone – Example 2 .....	48
Figure AA.7 – Application example for body detection of a VBPDST employing a volume as a detection zone .....	50
Figure BB.1 – Relationship between test piece position and the probability of detection .....	51
Figure BB.2 – Example for measurement of the probability of detection .....	52
Figure BB.3 – Relationship between detection zone and tolerance zone .....	54
Figure BB.4 – Overall minimum distance $S_0$ including tolerance zone .....	55
Figure CC.1 – Illumination model – Sphere illuminated by a point source .....	57
Figure CC.2 – Illumination model – Sphere illuminated by a half-Ulbricht sphere .....	57
Figure CC.3 – Brightness of a surface element of a sphere in spherical coordinates .....	58
Figure CC.4 – Brightness distribution in an image of a sphere .....	58
Figure CC.5 – Grey value profile over a sphere with low contrast for a typical imaging contrast (Modulation Transfer Function) .....	59
Figure CC.6 – Grey value profile over a sphere with the same colour as the background .....	59
Figure CC.7 – Grey value profile over a sphere in front of a background that is half as bright .....	60
Figure CC.8 – Grey value profile over a sphere in front of a background that is twice as bright .....	60
Figure CC.9 – Grey value profile over a sphere by low contrast .....	61
Figure CC.10 – Grey value profile over the sphere from Figure CC.9 but with the direction to the imaging device changed by $10^\circ$ .....	61
Figure CC.11 – Grey value profile over a small sphere that results in an image that is 5 pixels in diameter .....	62
Table 1 – Verification of detection capability requirements (see also 4.2.12) .....	25
Table 2 – Overview of light interference tests .....	30

## INTERNATIONAL ELECTROTECHNICAL COMMISSION

**SAFETY OF MACHINERY –  
ELECTRO-SENSITIVE PROTECTIVE EQUIPMENT –****Part 4-3: Particular requirements for equipment using  
vision based protective devices (VBPD) –  
Additional requirements when using stereo  
vision techniques (VBPDEST)**

## FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a technical specification when

- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 61496-4-3, which is a technical specification, has been prepared by IEC technical committee 44: Safety of machinery – Electrotechnical aspects.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
44/711/DTS	44/722/RVC

Full information on the voting for the approval of this technical specification can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

This part is to be used in conjunction with IEC 61496-1:2012.

This part supplements or modifies the corresponding clauses in IEC 61496-1:2012 to specify particular requirements for the design, construction and testing of electro-sensitive protective equipment (ESPE) for the safeguarding of machinery, employing vision based protective devices (VBPD) using stereo vision techniques (VBPDST) for the sensing function.

Where a particular clause or subclause of Part 1 is not mentioned in this Part 4-3, that clause or subclause applies as far as is reasonable. Where this part states "*addition*", "*modification*" or "*replacement*", the relevant text of Part 1 shall be adapted accordingly.

Clauses and subclauses which are additional to those of Part 1 are numbered sequentially, following on the last available number in Part 1. Terminological entries (in Clause 3) which are additional to those in Part 1 are numbered starting from 3.4301. Additional annexes are lettered from AA onwards.

A list of all parts in the IEC 61496 series, published under the general title *Safety of machinery – Electro-sensitive protective equipment*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

**IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.**

## INTRODUCTION

An electro-sensitive protective equipment (ESPE) is applied to machinery presenting a risk of personal injury. It provides protection by causing the machine to revert to a safe condition before a person can be placed in a hazardous situation.

The working group responsible for drafting this technical specification was concerned that, due to the complexity of the technology, there are many issues that are highly dependent on analysis and expertise in specific test and measurement techniques. In order to provide a high level of confidence, independent review by relevant expertise is required. They considered that if this high level of confidence could not be established these devices would not be suitable for use in safety related applications.

## **SAFETY OF MACHINERY – ELECTRO-SENSITIVE PROTECTIVE EQUIPMENT –**

### **Part 4-3: Particular requirements for equipment using vision based protective devices (VBPD) – Additional requirements when using stereo vision techniques (VBPDEST)**

#### **1 Scope**

##### *Replacement:*

This part of IEC 61496 specifies requirements for the design, construction and testing of electro-sensitive protective equipment (ESPE) designed specifically to detect persons or parts of persons as part of a safety-related system, employing vision-based protective devices (VBPDs) using stereo vision techniques (VBPDEST) for the sensing function. Special attention is directed to features which ensure that an appropriate safety-related performance is achieved. An ESPE may include optional safety-related functions, the requirements for which are given in Annex A of IEC 61496-1:2012 and this Technical Specification.

This part of IEC 61496 does not specify the dimensions or configurations of the detection zone and its disposition in relation to hazardous parts for any particular application, nor what constitutes a hazardous state of any machine. It is restricted to the functioning of the ESPE and how it interfaces with the machine.

The detection principle is based on the evaluation of images from different viewing points (stereoscopic view) for the determination of distance information. This distance information is used to determine the location of an object(s).

- This part of IEC 61496 is limited to vision based ESPEs with distances (stereo base) and directions between the different imaging devices fixed during manufacture.
- It is limited to vision based ESPEs, with a minimum distance from the sensing device to the detection zone of 4 times of the stereo base.
- It is limited to vision based ESPEs that can detect objects with at least 5 pixel diameter in the image plane.
- It is limited to vision based ESPEs that do not require human intervention for detection.
- It is limited to vision based ESPEs that detect objects entering into or being present in a detection zone(s).
- It is limited to VBPDESTs employing radiation at wavelengths within the range 400 nm to 1 500 nm.
- This part of IEC 61496 does not address those aspects required for complex classification or differentiation of the object detected.
- This part of IEC 61496 does not consider the aspects of a moving ESPE installation.

Additional requirements and tests can apply in the following cases:

- Use of multi-spectral (colour) techniques;
- Setups other than as shown in Figures of 4.1.2 (e.g. changing backgrounds, horizontal orientation of the optical axis with respect to the floor);
- Intended for outdoor applications.